SECURE
Protection Steels

RECOMMENDATIONS FOR

WELDING OF ARMOUR STEELS

ILSENBURGER GROBBLECH
A Member of the Salzgitter Group

RECOMMENDATIONS FOR WELDING OF ARMOUR STEELS

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Issue: 04/2022

1. GENERAL INFORMATION

Ilsenburger Grobblech produces heavy plates for ballistic protection with the brand name **SECURE**. These steels are primarily intended for civilian vehicles and buildings. The ballistic protection and the high hardness of 400 to 600 HB result from the special chemical composition in combination with a coordinated heat treatment by water quenching and tempering. To account for their alloy structure and high hardness certain measures must be considered to ensure safe welding.

Carbon equivalents for thickness up to 40 mm

Steel grade	CEV_{IIW}, typical	CET, typical
SECURE 400	0.72 %	0.47 %
SECURE 450	0.74 %	0.42 %
SECURE 500	0.72 %	0.47 %
SECURE 600	0.80 %	0.55 %

The cold cracking sensitivity of a steel can be estimated based on its chemical composition. The carbon equivalent CET (DIN EN 1011-2) derived from extensive cold-crack tests is particularly suitable for this purpose.

Calculation of carbon equivalents

IIW-formula

$$CEV = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Cu + Ni}{15}$$

CET-concept

$$CET = C + \frac{Mn + Mo}{10} + \frac{Cr + Cu}{20} + \frac{Ni}{40}$$

2. WELD SEAM PREPARATION

Careful weld preparation, i.e. uniform air gaps, web heights and seam openings, are a prerequisite to reduce residual stresses in the seam area and result in higher crack resistance.

Before starting to weld, the seam area must be cleaned. Scale, rust, or paint residues must be removed by brushing or grinding. It must also be made sure that the seam area is free of moisture by drying or preheating. The seam flanks should be inspected visually or by dye penetrant for separations and other defects interfering with welding such as slag residues.

3. WELDING CONDITIONS

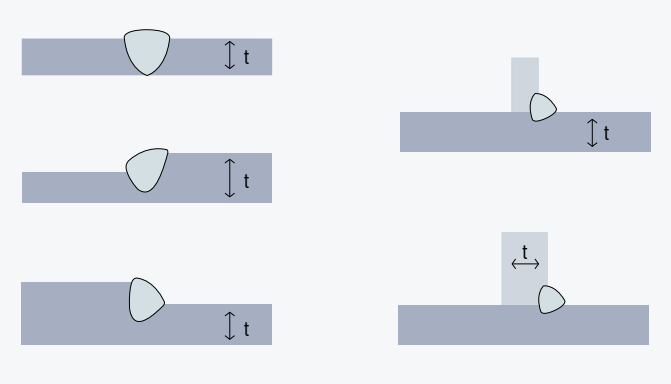
When welding safety steels, cooling times $t_{8/5}$ of between 5 s and 20 s should be observed in the seam area. Suitable welding conditions should allow for these cooling times, considering the required preheating temperature.

Joining with other steels is generally unproblematic if the welding conditions are adapted to **SECURE**.

For welding, select processes and filler metals which lead to the lowest possible hydrogen contents in the weld metal to avoid cold cracks in the weld area.

SECURE steels are preferably processed with austenitic filler metals. The parts to be joined should be at room temperature (min. 15 °C). For plate thicknesses above 25 mm, preheating to 100 °C to 150 °C is recommended also when welding with austenitic filler metals, taking into account the stresses to be expected in the weld area.

Relevant plate thickness t to determine the preheating temperature according to the CET concept



If ferritic filler metals are used, sufficient preheating of the weld area is always required. The preheated temperature must not drop until the welded joint is completed.

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With regard to the mechanical properties of the base metal, preheating temperatures and inner temperatures above 200 °C should be avoided when welding safety steels.

The following table shows the recommended preheating temperatures for MAG welding of safety steels with ferritic solid wires and a heat input of 1 kJ/mm as ruled by the largest single plate thickness in the weld area.

Energy per unit length E [kJ/mm]	
$E = \frac{U \cdot I \cdot 60}{v \cdot 10000}$	U = welding voltage [V] I = welding current [A] v = welding speed [cm/min]

Heat input Q [kJ/mm]	
Q = 0,8 · E	MAG welding, mixed gas M21 / arc welding, basic
Q = E	Submerged arc welding

For a more precise determination of the preheating temperature to be maintained in individual cases, the chemical composition specified in the certificate for the steel prevails.

4. WELDING FILLER METALS

When welding **SECURE 400**, **450**, **500** and **600** steels, the following austenitic filler metals have proven suitable:

Austenitic filler metals

Filler metal	Manual metal arc welding	Gas metal arc welding
Austenitic filler metal	DIN EN ISO 3581-A / E 18 8 Mn B 2 2	DIN EN ISO 14343-A / G 18 8 Mn

Regarding a good deformation capacity of ferritic welds, a non-alloyed filler metal should be preferred. This is particularly true when welding tack welds of thin plates or fillet welds, because here the weld metal is mixed up by the higher alloyed base metal. In manual arc welding, for example, it is advisable to use stick electrodes according to DIN EN ISO 2560-A: E 42 5 B 32 H5, for MAG welding wire electrodes according to DIN EN ISO 14341-A: G3Si1 have proved successful.

Preheating temperatures for MAG welding with ferritic filler metals. Heat input Q = 1.0 kJ/mm, hydrogen content HD = 2 ml/100 g

Grade	thickness t [mm]						
	6-10	≤15	≤ 20	≤ 25	≤ 30	≤ 35	> 35
SECURE 400	125 °C	150 °C		175 °C		200 °C	austenitic 100 – 150 °C
SECURE 450	75 °C	100 °C	125 °C			150 °C	
SECURE 500	125 °C	150 °C		175 °C		200 °C	austenitic 100 – 150 °C
SECURE 600	175 °C	200 °C	none	austenitic additives		100 - 150 °C	

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If higher strength is required in the welded joint, a matched filler metal should be used. When welding **butt welds** and multi-layer fillet welds with ferritic filler metals, the following filler metals have proven suitable:

Ferritic filler metals

Filler metal	Manual metal arc welding	Gas metal arc welding
Ferritic filler metal	DIN EN ISO 2560-A: E 42 4 B 42 E 42 5 B 32 H5 E 46 5 1Ni B 3 2 H5 E 50 6 Mn 1 Ni B 42 H5 DIN EN ISO 18275-A E 55 6 Mn1NiMo B T 42 H5 E 69 5 Mn2NiCrMo B 42 H5 E 89 4 Mn2Ni1CrMo B 42 H5 E 89 4 Mn2Ni1CrMo B42 H5	DIN EN ISO 14341-A G 3Si1 G 38 2 C1 3Si1 G42 3 M21 3Si1 DIN EN ISO 16834-A G Mn3Ni1Mo G Mn4Ni1,5CrMo DIN EN ISO 17632-A T 46 6 1Ni B M 2 H5 DIN EN ISO 18276-A T 69 6 Mn2NiCrMo B M 2 H5

To increase cold crack resistance, care must be taken to ensure that the hydrogen content of the weld metal is as low as possible. The filler metals must therefore be protected against moisture absorption during transport and storage. Stick electrodes and welding fluxes must be re-dried immediately before use in accordance with the manufacturer's instructions. The stick electrodes should then be kept at 100 °C to 150 °C until welding.

5. OTHER NOTES

In many applications it has been shown that welding safety steels of the **SECURE** series is mastered. Finally, note some practical recommendations which have proven to be effective in proper welding processing.

/ In case of fillet welds and high-quality requirements for the joints, it is recommended to remove the paint layer of primed plates in the weld area.

/ For tack welds, the tack length should be at least 50 mm. For plate thicknesses of more than 20 mm, it is recommended that tack welds be made in two layers.

/ Root beads should be ground before counter welding and, if the weld was cooled, they should be checked for freedom from cracks before welding is resumed.

/ In cover-pass welding, it is advantageous to weld in a sequence that prevents the last bead from touching the base metal.

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